Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 31
ISSUE 2
December
2008

Teaching manufacturing engineering at tertiary institutions in conjunction with engineering design and engineering materials

V. Kosse*, Iyer, Mahalinga-Iyer, P. Yarlagadda
School of Engineering Systems, Queensland University of Technology,
Brisbane, Queensland, Australia
* Corresponding author: E-mail address: v.kosse@qut.edu.au

Received 11.09.2008; published in revised form 01.12.2008

Education and research trends

ABSTRACT

Purpose: In this paper we discuss the innovative curriculum structure, teaching and learning approaches of coherent delivery of manufacturing in conjunction with engineering design and materials from year one to year four, including specializations, real life projects and final year projects.

Design/methodology/approach: Tertiary institutions now face serious challenges. Modern industry requires engineering graduates with strong knowledge of modern technologies, highly practical focus, management skills, ability to work individually and in a team, understanding of environmental issues and many other skills and graduate attributes. Institutions in the tertiary sector change courses and modify curriculum to reflect challenges of the modern industry and make engineering graduates better prepared for the "real world".

Findings: Queensland University of Technology, in response to industry requirements has re-designed the engineering curriculum with some integrated units. An integrated approach was adopted for the teaching of Materials Manufacturing and Design. This is further strengthened by various forms of final year projects. This includes industry based CEED projects as well as SAE Formula A Motorsport.

Practical implications: Queensland University of Technology in the recent years introduced an innovative structure of engineering courses with a common core for Bachelor of Engineering Mechanical, Infomechatronics and Medical, where manufacturing is taught in conjunction with engineering design and engineering materials.

Originality/value: Students survey indicates that the integrated approach enhances their learning and that the industry based projects help them to be better prepared for graduate work as well improving their communication skills.

Keywords: Development of new curricula for BSc and MSc studies in the field of materials science; Teaching; Tertiary institutions; Manufacturing; Design; Materials

1. Introduction

Engineering faculties at modern tertiary institutions under financial constraint face serious challenges. Modern industry requires engineering graduates with strong knowledge in current technologies, highly practical focus, management skills, ability to work individually and in a team, understanding environmental issues and many other skills and graduate attributes. Institutions in the tertiary sector restructure courses (also called programs by other institutions), modify curriculums to reflect challenges of the modern industry and make engineering graduates better prepared for the "real world". Queensland University of Technology in 2006 introduced an innovative structure of engineering courses with a common core for Bachelor of Engineering Mechanical, Infomechatronics and Medical. In the first year engineering students take an introductory unit (also called courses, subjects by other institutions) in engineering materials. In the First Semester of year two, students take a combined unit "Materials and Manufacture" which includes a project giving a combined view of design, materials and manufacture. This unit is followed in the second Semester by the first engineering design unit "Fundamentals of Mechanical Design". This unit includes design and build project. In the First Semester of year three, students take "Materials and manufacture 2" unit where advanced manufacturing technologies are discussed in conjunction with advanced materials technologies. Mechanical engineering students take the second engineering design unit "Design of machine elements", which includes a gearbox project. Infomechatronics students take "Design for manufacture" unit with main focus on product development. Biomedical students take "Bioengineering design" unit. Students in the basic mechanical engineering major have an opportunity to choose a second major or a minor. Significant number of engineering students carries out real-life projects through CEED program (Corporate Education for Enterprise Development) Cross-faculty projects are also done such as QUT motorsport with strong focus on real-life design and manufacture.

2. Structure of engineering courses at QUT

The engineering courses at QUT was recently re-designed to have a common core of fundamental engineering science and mathematics units followed by common set of units within the mechanical engineering related majors and then units that relates to the specialist area. However, the basic mechanical engineering major has the flexibility to broaden the knowledge in another area such as information technology and business by taking a minor consisting of four units. The specialised majors such as medical engineering and infomechatronics incorporate specific units that relates to the area. In the mechanical engineering major, the materials and manufacturing are combined because the properties of materials and how these properties can be used to shape the material can best be taught in the combined unit. All the majors also include a compulsory work integrated learning unit. This work integrated unit is the formalisation of work experience by incorporating some pedagogical principles as part of the curriculum. This unit allows the student to formally identify and further some generic objectives that were introduced in the class room.

3. Teaching materials and manufacturing

As indicated above, the materials and manufacturing were combined into two units running in second year and third year for the mechanical engineering major. The format of the teaching is to provide the students with the behavior of material under various conditions and then to supplement that with the manufacturing processes that uses these properties. In addition to the lectures the students in group are also required to do a project which gives them an understanding of the interrelationship between materials, manufacturing and design. In this project each group is given a small assembly, for example a small gear box, and asked to identify its function, its uses and the relationship between any physical parameters. In the case of the gearbox, student need to understand that it is a power transmission equipment and how power relates to torque and speed. Following this introduction, the students will de-assemble the assembly observing how it is done as well as any design features. The next step in the project is to identify and name the components using the correct technical terms. In doing so to note the special design features such as any locating surfaces, bearing surfaces, use of circlips, spacers etc. A brief introduction to graphical communication is given followed by sketching of the components. An interactive session is held to discuss the use of various materials of the components as well as a likely manufacturing method. By this time the students would have done material selection and a session with Cambridge Engineering Material Selector software. This allows the students to use the project as an example in material and manufacturing selection.

4. Reflecting manufacturing in engineering design

Engineering design is regarded by many as a backbone of the mechanical engineering Degree, because it brings together many fundamental and specialist engineering subjects. It is of high importance to reflect in teaching integration of engineering design, manufacturing and materials study, as well as maintenance because they determine to a large degree cost of manufacturing and performance of machinery.

At Queensland University of Technology (QUT) over the years an innovative structure of Engineering Degrees was developed and significant focus was placed on integration of manufacturing engineering with materials study and reflecting both areas in teaching engineering design. Engineering design units at QUT include the introductory unit ENB215 Fundamentals of mechanical design; ENB316 Design of machine Elements; and ENB317 Design and Maintenance of machinery. In all three units strong emphasis is made on manufacturing, materials selection surface and heat treatment.

In the ENB215 unit review of different production methods is carried out (including blank fabrication methods). Among important topics covered are life cycle of a product, tolerancing and hand drawing. An essential part of this unit is the Design and build competition. Students in small teams of up to six members have to design and construct a device that meets specifications and performs certain task. For example, in 2007 it was necessary to design and construct a device that being placed outside a 50mm circle puts inside a circle a 50 cent coin on its edge. Assessment items included: originality of the design concept, construction quality (the weight of the device, effective use of materials and overall dimensions influenced the score), performance of the device during the competition.

In the second design unit ENB316 among other machine elements students study joints (including threaded joints). An essential part of this unit is the gearbox project. Students carry out the design of the gearbox, select materials for major components, heat and surface treatment. For some components such as a gear and a shaft (or a pinion-shaft) students have to suggest machining methods and carry out analysis of these parts from the stand point of the ease of manufacturing.

In the third design unit ENB317 students study design and manufacture of equipment for special application (for example, heavy machinery, food processing and pharmaceutical equipment, equipment operating and elevated of sub-zero temperatures). Students also study maintenance and condition monitoring practices. An essential part of this unit is the lubrication project, which is an extension to the gearbox project. In this project students select lubricants, components of the lubricating system, suggest maintenance and condition monitoring system.

Some tutorial and lab sessions for design and manufacturing units are conducted in the Design Studio having numerous sectioned gearboxes and engines that help students to better understand the design and assembly methods of different machines. Some examples of teaching equipment available in the Design Studio is depicted in Figure 1.

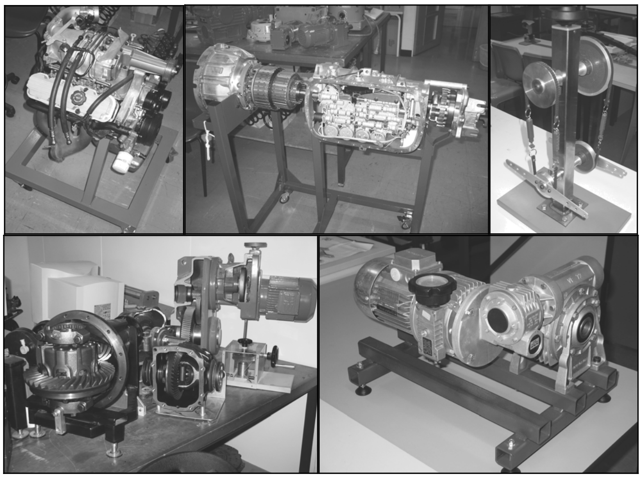

Fig. 1. Teaching equipment used in the Design Studio

Highly practical focus of design units and the blend of manufacturing and design enable students to appreciate the importance of addressing manufacturing issues at the design stage. Below are some students' responses :

"I have just completed a 12 month (paid) work experience contract with Holden Ltd in Melbourne as a student mechanical engineer. I was assigned to Power Train Reliability section, which looks after any reliability issues encountered in the current product and worked closely alongside the other engineers. My main task was monitoring reliability issues regarding the engine and transmission. I would like to say I found both design subjects 1 and 2 highly beneficial to the work I carried out during my time at Holden. I especially found the gearbox project for the 2nd design unit gave me a good grounding in both how the power is transmitted through the gearbox but also why and how certain design decisions are made. I have just begun Design and Maintenance of Machinery and this is highly relevant to the work I was performing at Holden. I believe to produce good engineers the university needs to take a more practical focus as I found I relied more heavily on the practical - "real world" application, which your design courses address".

Kind Regards, Benjamin

"I am writing to give you some feedback on your design units. I have found the units mmb381/mmb382 to be the best learning experiences of the units I have covered at university.
MMB381 was good as it incorporated the 3D modelling of Solidworks with Steve, which I have found to be a very useful tool. The gearbox design project, which involved 3d modelling, was very interesting and a 'real life' project. On work experience this year I received a similar project which required recommending a gearbox specification for a given power requirement of a coal conveyor.
MMB382 was useful as we were able to continue on our gearbox design project from the previous unit and develop a lubricating system. Studying OH&S also gave us a very strong message on the necessity of workplace safety.
I have enjoyed the integration of many fields and people in these units as we usually just cover one topic in other units".

Kind regards, Nick

5. Reflecting manufacturing in engineering materials

Integrating two areas of engineering in the curriculum is not new. Griffin and Creasy (2001) describes a new course combining two existing units (courses) into an integrated single unit combining materials and manufacturing. Similar examples can be seen in the curriculum integration examples of the US Foundation Coalition web site. In many instances the integration is only at a single unit level. However, at QUT the integration is over two units. Students learn the fundamentals of materials science in a first year level unit followed by two integrated materials and manufacturing units. The integrated project described earlier is in the first integrated unit. The project is done over a period of six weeks so as to give the students a chance to reflect on the various aspects of the project. The assembly used is a small worm reduction gear box. The students in groups are required to observe the de-assembly process and describe it in their report. The relationship between the various components is discussed in the class in an interactive manner. The students also make sketches of all the components; identify the materials of the various components as well as the manufacturing method of various components. Detailed discussion on the inter-relationship between various factors affecting the selection and manufacture of the component was discussed. During the de-assembly and assembly, several design issues were discussed especially on fits and location and alignment of components. The same gearbox is used in the design unit for issues related to gear design where the fits between components are re-enforced. The integrated unit is running in the past two years and the opinion of the students was gathered using a short survey after they have completed the exercise. The response rate of the survey was 55% in 2007 and 30% in 2008. Responses to two key questions, "How would you rate your experience in this project" and "The discussion periods help me explore the project better than a usual lecture" indicates that the integrated approach seems to promote active learning. Over 70% of the respondents, in both years, rated the project at 4 or better on a 5 point scale. About 10% of the respondents did not feel that interactive discussion help them learn more than in a normal lecture. Since the preferred learning style of students in a class varies, this response was not considered abnormal. Overall the indications are that this form of integrated approach helps in the learning of students.

6. Real-life projects

Apart from the exercises, integrated approach to learning and projects in the class room, the students also have the opportunity to participate in a real life project. Students can find their own project from industry or can be found for them through the School or participate in an organised competition that involves real world projects such as SAE Formula A (Formula Student) competition, unmanned air borne vehicles competition, ABB robotics projects. Two of these are described below:

6.1. CEED program

CEED stands for Cooperative Education for Enterprise Development. This program is run by a private company that communicates with different enterprises and identifies design and manufacturing-related problems that have to be addressed. Then a student is selected and assigned to particular company where he (she) carries out, in one semester, the final year project under a dual supervision from an academic supervisor and an industry supervisor. The CEED program enables to combine expertise of university academics and the industry and is highly beneficial to students involved in real-life projects. Some examples of CEED projects are:

- Development of mobile lifting devices for the Australian Defense that enables loading and unloading of containers in field environment;
- Cost-benefit analysis of different design and manufacturing concepts of electric sub-stations for ABB Australia;
- Development of new locking devices for movable walls for Centor Australia, and many other projects.

CEED has been running for the past 15 or so years and has completed more than 500 projects from industry. At the end of a CEED project, the industry is surveyed to gauge the usefulness of the project. Overwhelmingly, the response of the industry has been positive. Students gain valuable industry experience as well as improve their communication skills.

6.2. QUT Motorsport

QUT Motorsport project is a unique project arranged under the umbrella of the SAE Formula A (Formula Student) competition when students' teams design and build a small racing car with an engine displacement under 600cm^3. Compared to other universities at QUT this project has become a truly cross faculty project engaging engineering students (mechanical, aerospace, electrical, electronics, mechatronics), information technology, business, art, journalism, industrial design, and many other specialties. The students' team advised by an academic supervisor plans the development of a racing car, communicates with sponsors, designs and builds the car, tests it and takes to the competition in Melbourne. During the competition students give several presentations (including the Design and Manufacture presentation), the car is subjected to different static and dynamic tests including endurance test on a track. Students maintain a Web-site, prepare promotional materials and participate in promotional events. The project involves students from year one to year four. According to the rules for six months after graduation former students can be part of the team and go to the competition. This enables knowledge transfer to new comers. Students participating in the project gain valuable experience of working in a multi-disciplinary team on a real-life project. The success of the QUT Motorsport project resulted in the introduction at QUT of the first in Australia specialization (the Second Major) in Motor Sport. This specialization includes a group of eight core units including a new design unit ENB315 Motor Racing Vehicle Design. Figure 2 depicts the QUT Motorsport team at the national SAE Formula A competition in Melbourne. Students participating in the racing car project gain valuable hands on experience in design, materials selection and manufacture of a small racing car. Students also establish close links with suppliers of motor racing car components. It is not surprising that all students participating in the racing team receive job offers before graduation.

Fig. 2. QUT Motorsport team during national SAE competition

7. Conclusions

Queensland University of Technology, in response to industry requirements has re-designed the engineering curriculum with some integrated units. An integrated approach was adopted for the teaching of Materials Manufacturing and Design. This is further strengthened by various forms of final year projects. This includes industry based CEED projects as well as SAE Formula A Motorsport. Students survey indicates that the integrated approach enhances their learning and that the industry based projects help them to be better prepared for graduate work as well improving their communication skills.

References

[1] V. Kosse, Solving Problems with TRIZ – an Exercise Handbook, Ideation International Incorporation, USA, 2004.

[2] J. McGourty, K.P. De Meuse, The Team Development – An Assessment and Skill Building Program, John Willey & Sons, 2001.

[3] G.B. Griffin, T.S. Creasy, The Development of a Combined Materials and Manufacturing Process Course at Texas A&M University, Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition, Session 2464, 2001.

[4] www.foundationcoalition.org - Foundation Coalition, (accessed 20th June 2008).